

Teaching Activity: The Greenhouse Effect: Fact or Theory?

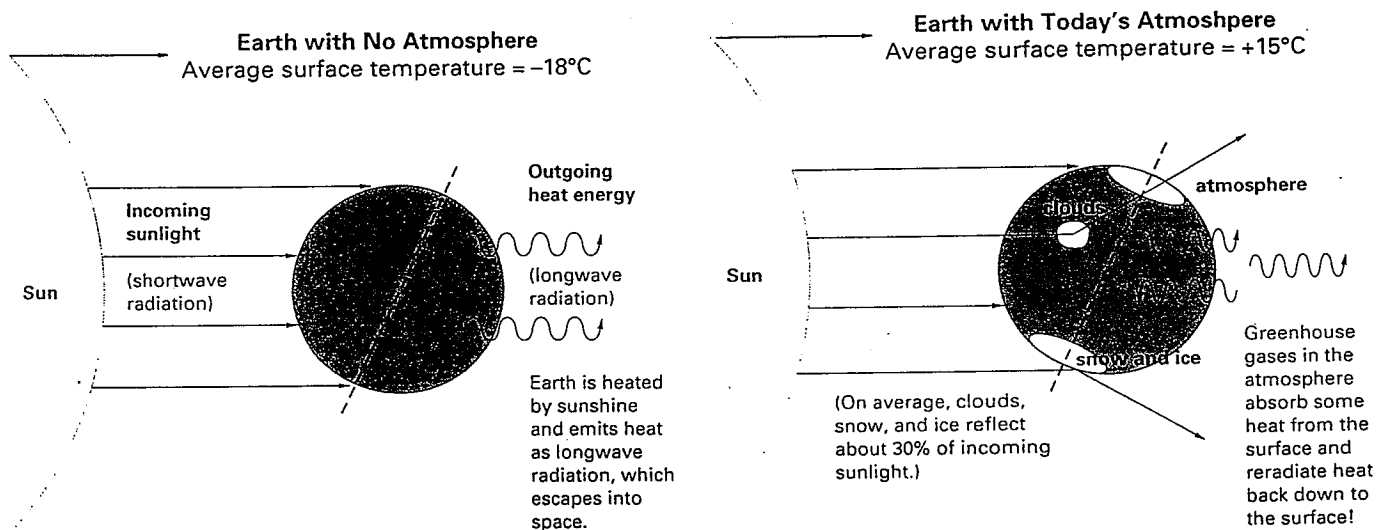
Introduction:

What is the greenhouse effect?

The Earth's global average temperature is caused by:

- 1) sunlight received;
 - 2) sunlight reflected
- and 3) heat energy trapped and reradiated back to Earth by the atmosphere.

Without an atmosphere, incoming solar radiation (sunlight) and outgoing radiation (heat energy) would be balanced and the Earth would have an average surface temperature of about -18 C (0 F). However, the Earth has an atmosphere which contains certain gases which trap some of the outgoing heat energy. These gases have the ability to absorb the heat energy radiated by the Earth and then "reradiate" it back to the surface. This process is called the *greenhouse effect* and the gases involved in it are called *greenhouse gases*. It is a natural and necessary process in the Earth system and maintains a global average temperature for the Earth of about 15 degrees C (59 F).



The greenhouse effect of the atmosphere on Earth's average temperature

Scientists know that the greenhouse effect exists and that without it Earth's temperature would be far too cold to support life as we know it. Surface temperatures on nearby planets like Mars and Venus also depend on the strength of their own greenhouse effects. A planet's ability to trap longwave radiation determines its surface temperature. In the table that follows, Earth is defined as having an ability to trap longwave radiation equal to 1; figures for Venus and Mars are relative to Earth with higher numbers indicating a greater ability to trap longwave radiation. Notice what the temperatures would be on each of these planets if there were no greenhouse effect, that is, if their atmospheres trapped no longwave radiation. Venus would actually be colder than Earth, despite being nearer to the Sun. Mars shows little difference because its atmosphere already has a weak greenhouse effect. Mars is too cold, Venus is too hot, Earth is just right--- what some planetary climatologists refer to as the "Goldilocks Effect".

The greenhouse effect on three terrestrial planets

	Surface temp. without a greenhouse effect	Planet's actual ability to trap longwave radiation*	Actual average surface temp.
Venus	-40°C	100	427°C
Earth	-18°C	1	15°C
Mars	-56°C	0.1	-53°C

What gases cause the greenhouse effect?

Carbon dioxide and water vapor are the two main greenhouse gases. However, there are other important greenhouse gases in the atmosphere: methane (CH₄), nitrous oxide (N₂O), chlorofluocarbons (CFCs), and ozone (O₃). Carbon dioxide and methane come from both natural sources and human activities. CFCs are synthetic gases that were first manufactured in the 1940's and are used in many industrial products. Water vapor comes mainly from evaporation of the oceans. The concentrations of all these gases in the atmosphere have increased since the Industrial Revolution began in the 1800's.

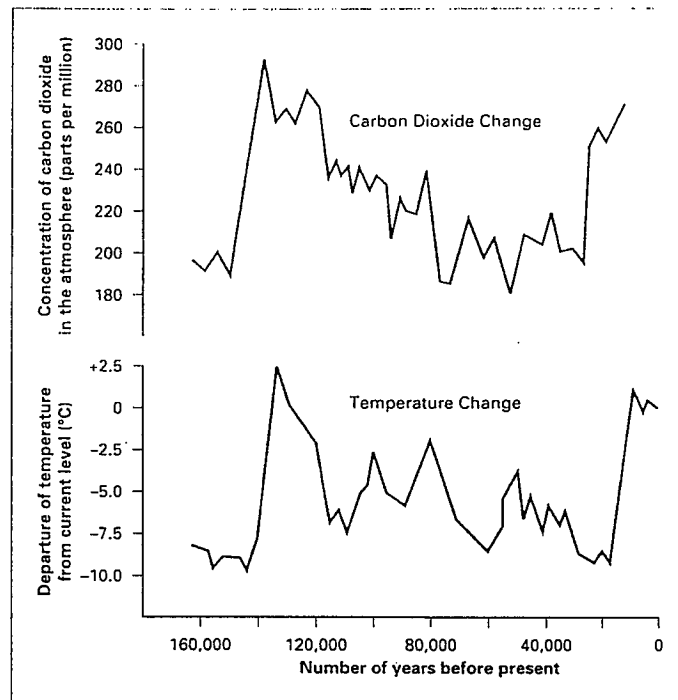
	1850 estimated average concentration	1980 measured average concentration	1990 measured average concentration	2030 probable average concentration
CO ₂	260,000	338,500	353,000	450,000
CH ₄	750	1,554	1,720	2,340
N ₂ O	280	296	310	375
CFCs	0	0.49	0.76	3.10

Increases of greenhouse gas concentrations in Earth's atmosphere 1850-2030

What effect could an increase in greenhouse gases have?

Scientists know that the greenhouse effect causes the Earth to be warmer than it would be if it had no atmosphere. They also know that the concentrations of greenhouse gases have been increasing steadily since the mid-nineteenth century. These are *scientific fact*.

Will the Earth get warmer as the atmosphere traps more and more heat? Will the atmosphere re-radiate so much heat back to the surface that the whole planet will heat up? Many scientists think that it will and refer to it as the "enhanced" greenhouse effect. This *hypothesis, or theory*, that the enhanced greenhouse effect will cause Earth to heat up is called "*global warming*". The best evidence to support this idea comes from studies of temperature and atmospheric gas concentrations in the past from ice core samples taken in Antarctica and Greenland. They indicate a link between the amount of greenhouse gases in the atmosphere and global temperature change.



Long term trends in temperature and atmospheric CO₂

Scientists think that the predicted global warming will be large compared to historical temperature changes. In the last 2 million years, the temperature has been more than 2-3 degrees C warmer than it is today. In the last 100,000 years, it has been almost 1 degree C warmer, and in the past 1,000 years, at most 0.5 degrees C warmer. Earth has warmed about 4 degrees C since the last Ice Age, and about 0.4 degrees C in the last century. In addition, we know that eight of the ten warmest years since 1850 have occurred since 1980. The question is :Do these fact *prove* that the climate is warming up or is it circumstantial evidence?

Objective:

- To understand the greenhouse effect;
- To recognize the difference between a scientific fact (the greenhouse effect) and an unproven scientific hypothesis (global warming);

Important Terms: Carbon dioxide, enhanced greenhouse effect, global warming, greenhouse gases, longwave radiation, shortwave radiation;

Materials: Copy of activity, "The Greenhouse Effect: Fact or Theory", transparency of the greenhouse effect, paper/pencil;

Procedure:

I. What is the greenhouse effect?

1. Have students read the section "What is the greenhouse effect".
 - Discuss the diagram included with the text.
 - Using their notes and the information from the reading, they should label the steps in the diagram of the greenhouse effect in their packet.
2. Referring to the table showing the effect of the greenhouse effect on three terrestrial planets, have students compare the surface temperatures without a greenhouse effect for the 3 planets.
3. Referring to the column "Actual average surface temperature", have students write a paragraph accounting for the term the Goldilocks Effect.
4. Students should then respond to the questions in the **Analysis and Comprehension** section for part I.

II. What gases cause the greenhouse effect?

1. Have students read the section "What gases cause the greenhouse effect?"
 - Discuss the information with them from the text and the table of increases in greenhouse gas concentrations.
 - Clarify the meaning of parts per billion (ppb) and parts per million (ppm).
2. Have students write a paragraph describing what the table in this section shows.
3. Have students graph the concentrations for the greenhouse gases listed on the graph in their packet for 1850, 1980, 1990 and 2030.
 - Students should calculate the percentage rate of growth for each gas.
4. Students should then answer any questions in the **Analysis and Comprehension** section for part II.

III. What effect could an increase in greenhouse gas concentrations have?

1. Have students read the section, "What effect could an increase in greenhouse gas concentrations have?"
 - Discuss the text and the graph of long term CO_2 and temperature trends.
 - Point out the scientific controversy that arises when the accepted facts are used to hypothesize the likelihood of global warming. In sum: greenhouse effect = scientific fact; global warming = scientific hypothesis.
 - Have students create a chart where they itemize the information for each topic: greenhouse effect vs. global warming. See below:

<i>Greenhouse effect</i>	<i>Global warming</i>

- After making the chart, have students, acting as jurors, state their opinion whether these data are proof that global warming has begun. Students should include any suggestions they have for additional information or data that might help to clarify the issue.

(NOTE: Student opinions will of course vary. Note that the data presented to make the case for global warming are only circumstantial. However, taken together, the data displayed during this lesson make for a stronger case: the Goldilocks Effect, ice core data, temperature data since the start of the Industrial Revolution.)

3. Students should now complete any questions relating to part III in the **Analysis and Comprehension** section.

Student Activity Sheet #1: The Greenhouse Effect: Fact or Theory?

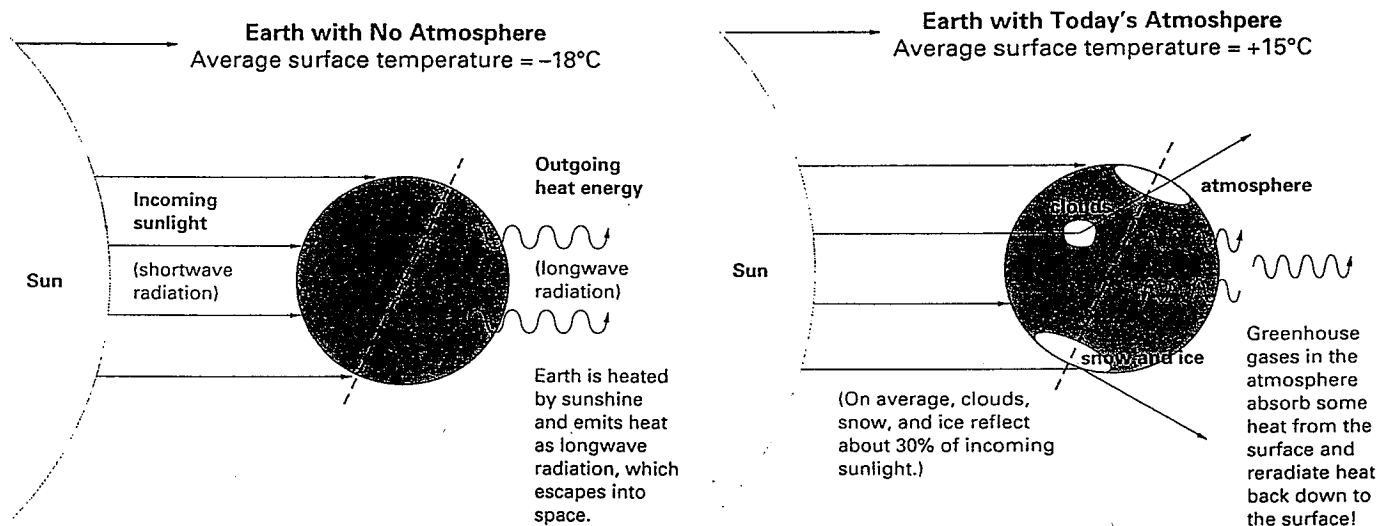
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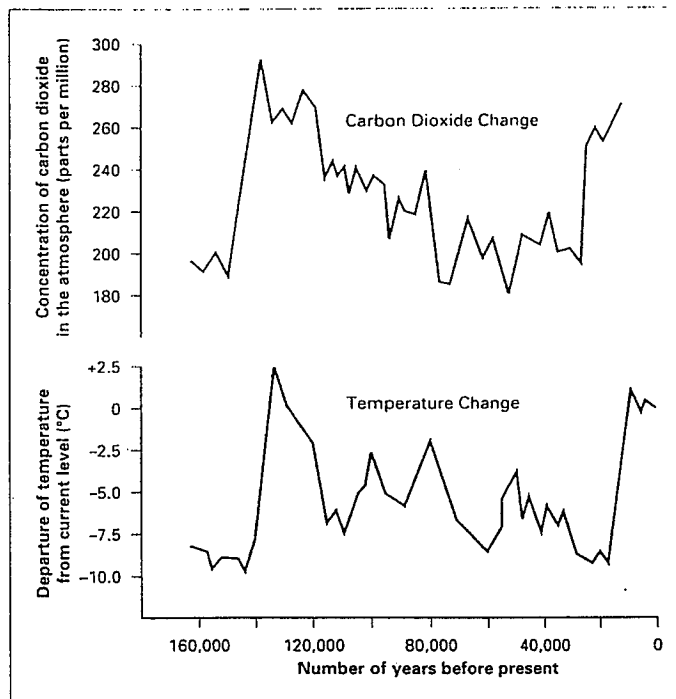
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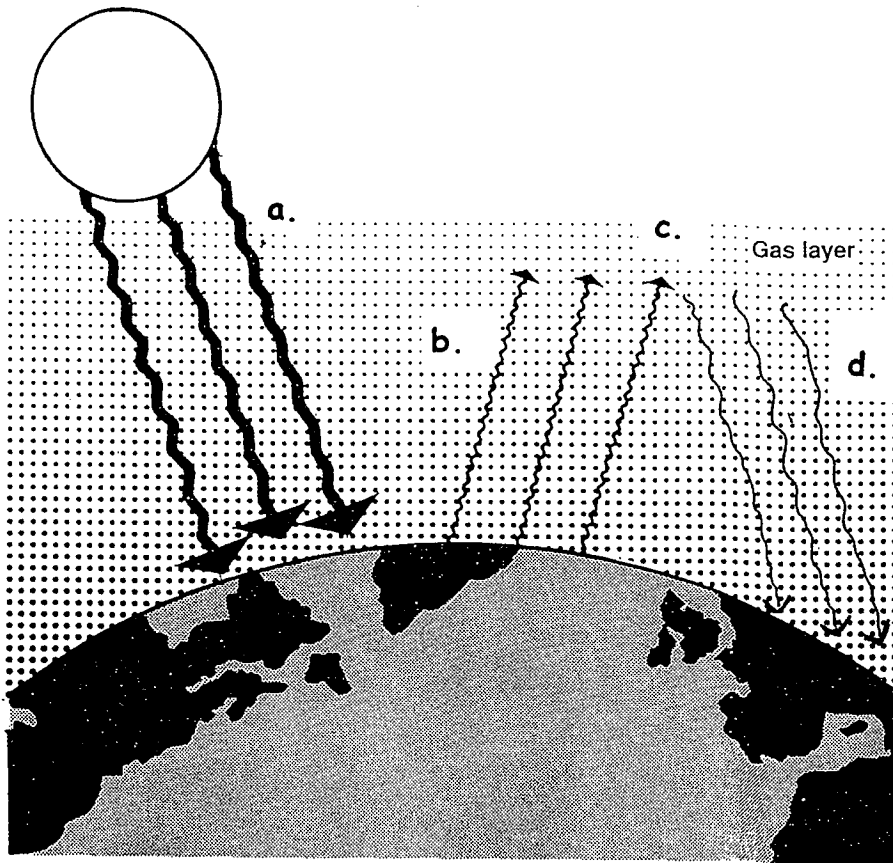
Important Terms. Carbon dioxide, enhanced greenhouse effect, global warming, greenhouse gases, longwave radiation, shortwave radiation;

Materials: Copy of activity, "The Greenhouse Effect: Fact or Theory", transparency of the greenhouse effect, paper/pencil;

Student Activity Sheet #2:

I. What is the greenhouse effect?

1. Using the information from the reading and your notes, label the steps, a-d, in the diagram of the greenhouse effect below. Write the information in the spaces provided.



a. _____

b. _____

c. _____

d. _____

2. Refer to the table showing the effect of the greenhouse effect on three terrestrial planets and write a paragraph comparing the surface temperatures of the 3 planets without a greenhouse effect.

3. Using the same table as in #2 above, refer to the column "Actual average surface temperatures". Write an explanation for the term "Goldilocks Effect".

4. Answer the questions in the Analysis and Comprehension section that refer to part I.

Part II: What gases cause the greenhouse effect?

1. Write a paragraph explaining what the table, "Increase in greenhouse gas concentrations" in this section shows.

2. Create a graph of the greenhouse gas concentrations listed for the years: 1850, 1980, 1990 and 2030.

- Label the X-axis : Year
- Label the y-axis : Greenhouse gas concentrations (ppm)
- Calculate the percentage rate of growth for each gas.

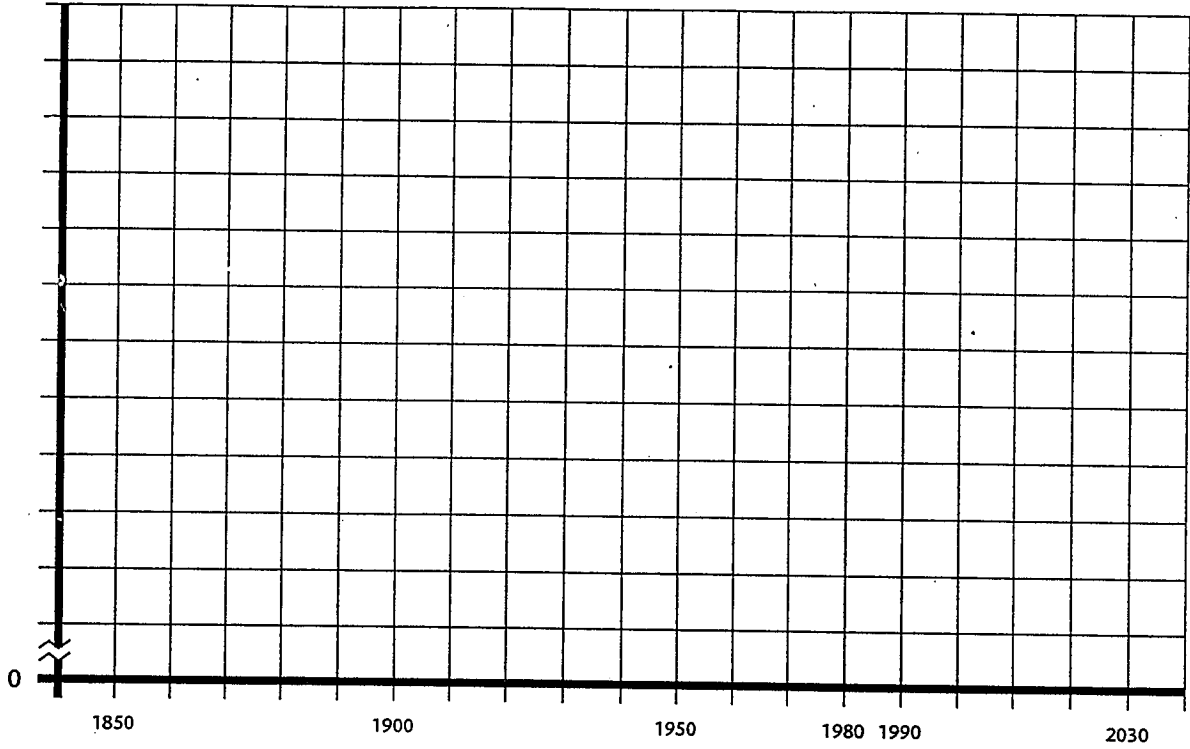
CO₂= _____ annual growth rate

CH₄= _____ annual growth rate

CFCs= _____ annual growth rate

N₂O= _____ annual growth rate

Trend of Greenhouse Gases in the Atmosphere 1850-2030



3. Answer any questions in the Analysis and Comprehension section that refer to part II.

III: What effect could an increase in greenhouse gas concentrations have?

1. After reading the information from this section, complete the chart below by itemizing the information for each topic: greenhouse effect vs. global warming.

Greenhouse Effect	Global warming

2. When you have complete the chart, write a paragraph in which you state your opinion as to whether these data are proof that global warming has begun. Include any suggestions that you might have for additional information or data to help clarify the issue.

3. Answer any questions in the **Analysis and Comprehension** section that relate to part III.

Student Activity Sheet #3: Analysis and Comprehension:

1. What 3 things are responsible for the Earth's average global temperature?
 - a. _____
 - b. _____
 - c. _____

2. Explain what a greenhouse gas is. Name two greenhouse gases.

3. What is the Earth's average global temperature with the greenhouse effect? Without it? _____

4. Name two parts of the Earth system that are heat reflectors and two that are heat absorbers. _____

5. In a diagram of a greenhouse, what would the glass roof represent? _____

6. How are the glass in the greenhouse and the gases in the atmosphere the same?

7. The glass panels in a hypothetical greenhouse are 1 inch thick. If we replaced these panels with glass 2 inches thick, what do you think would happen to the heat holding ability of the greenhouse? _____

8. A cubic centimeter of healthy atmosphere contains about 280 molecules of a heat absorbing gas. If the number of molecules increases to 400, what should happen to its ability to hold heat? _____

9. On your graph of the greenhouse gases, which line segment is steeper: the segment for 1850-1980, or the segment for 1980-1990? _____
What does this change indicate? _____

10. The 1850 concentrations are probably similar to what the atmosphere contained before the Industrial Revolution. All these "preindustrial" concentrations are estimates except for CFCs. How do we know their preindustrial concentration was zero? _____

11. According to the table of long term trends in CO₂ concentrations and temperature, what seems to be the relationship between them? _____

12. By about how much has the Earth's temperature increased in the last 1 million years? _____
Since the middle 1800's? _____

13. The Earth has approximately 69,000,000 m² of heat receivable surface area. Each meter² receives about 1380 Watts (W) of heat energy every day. This amount is called the *solar constant*.

a. Compute the amount of heat that reaches the Earth's surface on an average day.
(NOTE: Total surface area x solar constant = Total heat received)

b. Compute the total amount of heat retained by the Earth's surface (47%).
(NOTE: Total amt. received x percent absorbed = Total Amt. Absorbed)

c. What is the difference in the amount of radiation received (100%) and the amount returned to space?
